HAL open science

Analysis of synchrony of a handshake between humans

Artem Melnyk, Vladimir Borysenko, Patrick Henaff

▶ To cite this version:

Artem Melnyk, Vladimir Borysenko, Patrick Henaff. Analysis of synchrony of a handshake between humans. AIM 2014 - IEEE/ASME International Conference on Advanced Intelligent Mechatronics, Jul 2014, Besançon, France. pp.1753-1758, 10.1109/AIM.2014.6878337 . hal-01111248

HAL Id: hal-01111248
https://hal.science/hal-01111248

Submitted on 18 Jan 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Analysis of Synchrony of a Handshake Between Humans

A. A. Melnyk , V. Ph. Borysenko and P. Hénaff

Abstract— **Physical and social interaction between humans and robots are important for humanoid robotics. In this article the characteristics of a handshake between humans are physically examined aiming at future experiments with a handshake between a human and a robot. A special pair of data gloves has been designed to measure quantitative characteristics of a handshake ritual such as duration, strength of the grip, and frequency of the rhythmic movements. Experiment results show that handshaking consists of four phases. After a physical contact, a mutual synchrony appears between the two persons. A statistical analysis shows that the frequency of this synchronization is around 4 Hz and average strength of the grip is 2.5 N.**

I. Introduction

Usually, robots are used for a special set of tasks. The parameters of their environment are known and constrained and they do not perform any unexpected interaction until they are reprogrammed. The priorities of a large number of robots which work in industry are their accuracy and speed.

Advances in artificial intelligence and robotics are now looking to challenges in non-constrained robot environments [1], [2]. More flexible and intelligent control systems are designed to create adaptive robots able to perform new tasks, interact or work with humans. Robots will become adaptable, acquire learning abilities and exhibit new behavior corresponding to any change in their environment [3]-[5].

In the near future, the humanoid robot will appear in the human environment as a companion to help or to work with the humans. This raises the relevant question of interaction between a human and robot in a human –friendly behavior. The social robot is a focus of attention of researchers in robotics, psychology, neuroscience and sociology. There are works about security [6] and a real role of a robot [7]-[9] in the human environment. A great number of researches have been carried out in the field of physical Human-Robot Interaction (pHRI) wherein handshaking is an important subject [10]-[13]. Human- robot interaction has been studied through the handshaking action [14]. In [15] the authors propose a hybrid deliberate/reactive model to achieve natural handshaking between a human and a robot and they compare the trajectory and interaction force during the human-human and human-robot handshaking.

The origin of nonverbal human communication like handshaking goes back to extreme antiquity and investigations in human psychology are giving rise to comprehensive study of this social phenomenon. Handshaking has an important social function of regulating and maintaining human interactions [16], [17], and it is a universally accepted pattern of behavior in societies that initiates and constitutes social interaction [18]. Some works show that there seems to be a strong association between poor handshaking skills and autistic psychopathology [19]. According to [20] a handshake provides the information about the person character. Several studies show that specific handshake manners may depend on personality traits [21]. In [22] it is shown that handshake characteristics like completeness of grip (forces), strength, duration, vigor (frequency) and others are related to particular orthogonal factors of personality. The authors define a set of qualitative characteristics related to impressions of the experiment participants. Thus, one can imagine that in future a humanoid robot will be able to handshake with humans like humans and why not with different personality characteristics. This paper aims to better understand a handshake between humans. Experiments are carried out aiming at a quantitative analysis of a handshake, especially the synchrony phenomenon that appears when the hands of two humans interact. Coupling energy of interaction between oscillating systems causes synchronization and it is defined as an adjustment of frequency of one or both of the coupling objects (mutual adjustment) [23]. This nonlinear phenomenon is well-known in biological and physical systems where various oscillating systems interact and start to behave synchronously by adjusting their own frequencies. For example, two people walk synchronously after a few tens of steps, the choristers heart rhythms are synchronized while singing, the breathing of a baby synchronizes with the breathing of its pregnant mother. Moreover, an interesting aspect of the phenomenon of synchronization in human interactions is its unintentional nature.

Several researches in psychology take into account the concept of synchrony for its important role in early development, language learning and social interaction. As humanoid robot actions will occur in a social context, the phenomenon of synchrony is now being studied in such fields as social signal processing, machine learning and robotics [24]. In [25], the authors describe the mechanism of Human-Robot Interaction which is initiated by synchrony detection. In [26], human motor coordination responses indicate that the participants tend to synchronize with agents with better overall perception. Based on the results of this experimental study, the authors suggest that a humanoid robot with good overall perception as a "social entity" may facilitate "engaging" interactions with a human. In [27], [28], the authors show that the synchrony between a human and a robot arm when they interact in a handshaking situation can be learnt using adaptive oscillators or central pattern generators (CPG).

V. Ph. Borysenko and A. A. Melnyk are with the Electrical Engineering Department, Donetsk National Technical University, 83001, Ukraine.
A. A. Melnyk is a PhD student between Donetsk National Technical University and University de Cergy-Pontoise in ETIS Lab, UMR 8051, UCP-ENSEA-CNRS, (artemmelnyk@gmail.com).
P. Hénaff, is with LORIA UMR 7503, University of Lorraine-INRIA-CNRS, F-54506 Nancy, France (patrick.henaff@loria.fr).

In this paper, the characteristics of a handshake between humans are physically examined aiming at future experiments with handshakes between a human and a robot. A special pair of data gloves has been designed to measure quantitative characteristics of a handshake ritual such as duration, strength of the grip, and frequency of the rhythmic movements.

After this introduction, the second part of this paper describes the proposed materials and methods to measure handshake synchrony. The third part presents the experiments. Analysis of the synchrony during several handshakes between various couples of humans is carried out. Finally, the conclusion and perspectives are given in the fourth part.

II. Materials and Methods

A. Materials

To measure human handshake characteristics, a customized wearable experimental setup has been designed (see [29] for more details). It consists of a set of several sensors (accelerometers, gyroscopes and force sensitive resistors) attached to a glove, and of a microcontroller for signal acquisition and conditioning. Our system allows reproducible experiments to quantify handshake characteristics such as duration and strength of the grip, vigor and rhythmicity of a handshake. Compared to the commercially existing systems (which are not available in Ukraine) our system is cheaper and it allows measuring hand grip force simultaneously with acceleration. The glove equipped with six degrees of freedom (6 DoF) inertial measurement unit (IMU) and six force sensitive resistors (FSR) transduces hand movement parameters and interaction force values. The FSR are glued on the palm region of the glove to get the data about the fullness of the grip of two interacting hands (Fig.1a). The 6 DoF IMU is attached to each glove on the back of the palm (opisthenar). It provides three linear accelerations and three angular velocities. Accelerations allow measuring vigor of a handshake and angular velocities allow reconstructing the motion of the hand for other experiments not presented in this paper. Fig. 1b and Fig. 1c present the sensing axes of the 6 DoF IMU. Position of the FSR on the hand allows measuring the distribution of the forces during the grip and then how each person grips the hand of the other person.

The characteristics of the sensors are given in Table 1. The current values of accelerations are processed in real time with a sampling time of 20 ms by a 16 MHz microcontroller ATmega2560 and sent asynchronously via USB port to the remote computer after filtering and transformations of coordinate systems.

TABLE I. Applied Inertial Units

Measured value	***Sensor***	***Range***	***Analog input***
Acceleration, a_X, a_Y, a_Z	ADXL335	±3g	ADC 0…2
Velocities, w_X, w_Y	PR530	300 s^{-1}	ADC 3…4
Velocity, w_Z	LY530	300 s^{-1}	ADC 5
Force, f_i	FSR	10 kg	ADC 6…11

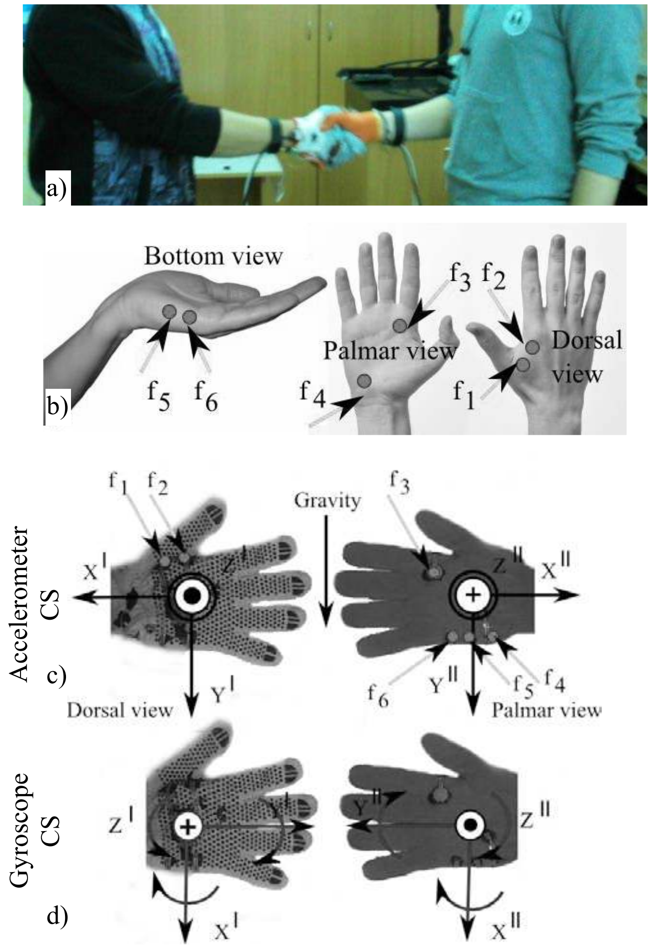

Figure 1. Two interacting subjects carrying the prototype system. a) the data gloves (subjects I and II); b) the six force sensitive resistors (above sensors position on the hand is shown); c) local coordinate system (CS) for accelerometers; d) local coordinate system for gyroscopes.

B. Methods

The dynamics of interaction between two hands during a handshake is investigated to examine the phenomenon of synchrony. The Phase Locking Value index (PLV) is used to compute the phase difference between the accelerations of the two human hands. PLV is a method presented by Lachaux et al. for detecting EEG synchrony in a band of frequencies [31]. The PLV is obtained after having applied filtering and a convolution with a complex Gabor wavelet on the two signals (see [31] for more details). The PLV value is close to 1 for synchronized signals and approaches 0 otherwise. In our experiments, the PLV is defined by:

$$-\left|\sum exp\left(i(\emptyset(t \qquad (t))\right)\right| \qquad (1$$

where $\emptyset_I(t), \emptyset_{II}(t)$ are the phases of the accelerations (t), a_{II}(t) measured on person *I* and *II*. $(\emptyset_I(t) - \emptyset_{II}(t$ is the phase difference between the two signals and *N* is the number of samples. The parameters of the PLV process are fixed for analysis of natural arm movements in accordance with the work presented in [31].

III. EXPERIMENTAL RESULTS OF HANDSHAKING

A. Experimental setup

Two persons were equipped with our system of sensors and were proposed to start a casual handshake. The persons were allowed looking and speaking to each other for more natural experimental conditions. They stood at arm length, so they did not have to do any additional movements except handshaking (Fig. 1). Before starting handshaking, a two-stage calibration procedure was applied to obtain adequate measurements from the sensors. During the first stage the subjects did not move, they were in their natural standing position with arms lowered down. During the second stage the subjects were asked to produce, with their hands in front of them, several elementary movements (pronation, supination, flexion, extension, ulnar, radial deviations). A set of five successive handshakes is presented in Fig.2 for the subject I and subject II. The first subfigure shows the acceleration from the x axis of the accelerometer (sagittal plan), the second and third subfigures depict accelerations on y (sagittal plan) and z-axis respectively (frontal plan). The fourth subfigure depicts mean forces on the data glove of two persons (upper-side f_1, f_2, f_3 and lower-side f_4, f_5, f_6 sensors of the data glove). The average duration of a handshake is 2.67 seconds (with a standard deviation 0.86 s) and a pause (an interval between two handshakes) is 3.57 s (with s standard deviation 0.69 s). The maximum acceleration does not exceed 4.1 g. In this part of the work the average of the forces are only used to determine the physical contact. The average grip force f_m is around 3.5 N. The subject I seems to be stronger than the subject II. This characteristic will be utilized in other experiments to classify the personality of subjects.

B. Handshake analysis of one pair of persons

On the Fig. 3 the analysis focuses on the third handshake of Fig.2 those (from 14s to 20 s). The accelerations measured on the hands show that handshaking is a phenomenon that can be decomposed into four phases. In phase 1, a visual contact is established, and the persons bring their hands to start the shake (start of handshake: SoH). In phase 2, a physical contact (PhC) is established, and the participants are in the first phase of the interaction, unconsciously synchronizing their movements. In phase 3, movements are mutually synchronized (MS), and handshake continues. Phase 4 corresponds to the end of the handshake (EoH), physical connection is broken, and hands freely move back to subjects' bodies. The PLV indicates that synchrony appears after 0.5 s (before the interaction, the PLV value is low) and is maintained until the end of the handshake

The accelerations also show that the main movement occurs in the sagittal plane. Indeed, the acceleration values on x and z axes must be modified taking into account the rotation of the hands during the movement (this rotation is not currently corrected). In fact, x and z accelerations are smaller compared to the acceleration on y axis. Thus only y axis data are considered for analysis. The angular velocities are depicted in Fig. 4. In the phase of MS, the maximum is ±200 ∘/s, while at the beginning of the transition phase PhC velocity is ±500 ∘/s before its attenuation.

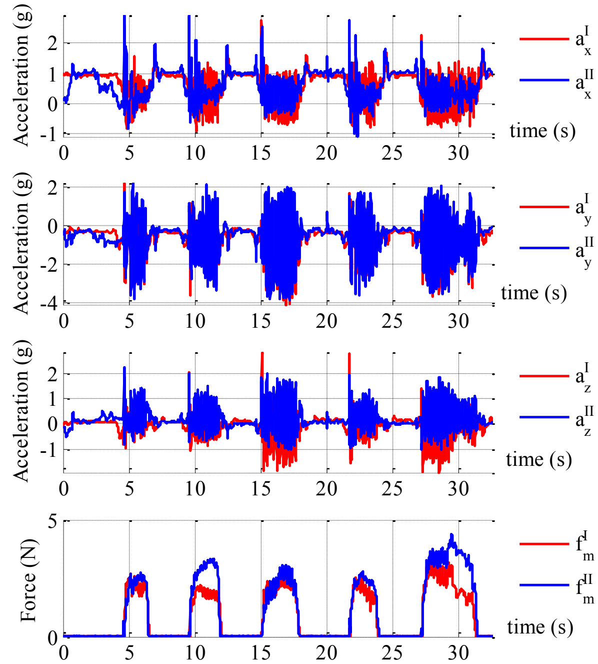

Figure 2. Accelerations and average forces measured on the two human arms during five handshakes.

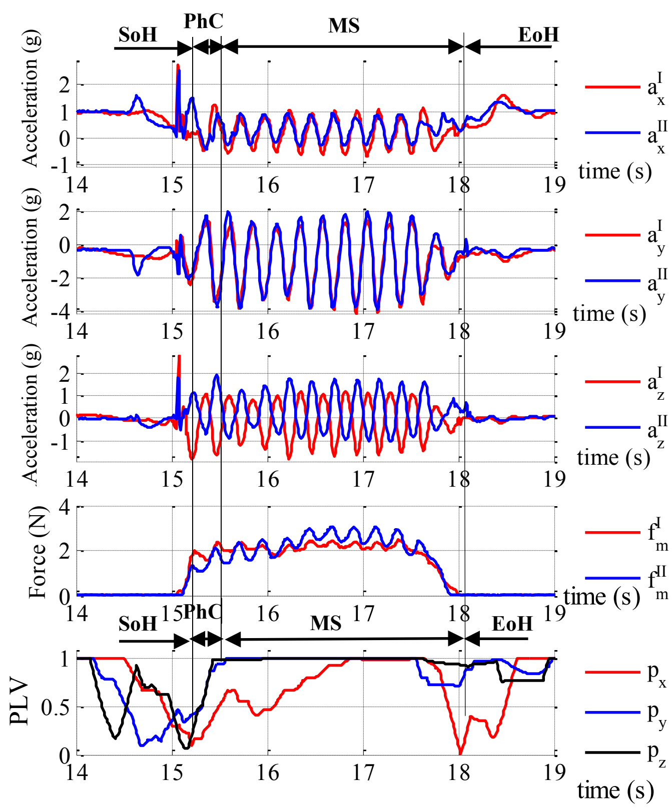

Figure 3. Acceleration measured in the coordinate frame of the IMU during a handshake and PLV. Axes z of the two subjetcs are opposed (see Fig. 1). The PLV is computed on accelerations. The p_X (respictevely: p_Y and p_Z) is PLV result of a_X (respictevely: a_Y and a_Z) using eq.(1). The forces are averaged on the six sensors of two persons.

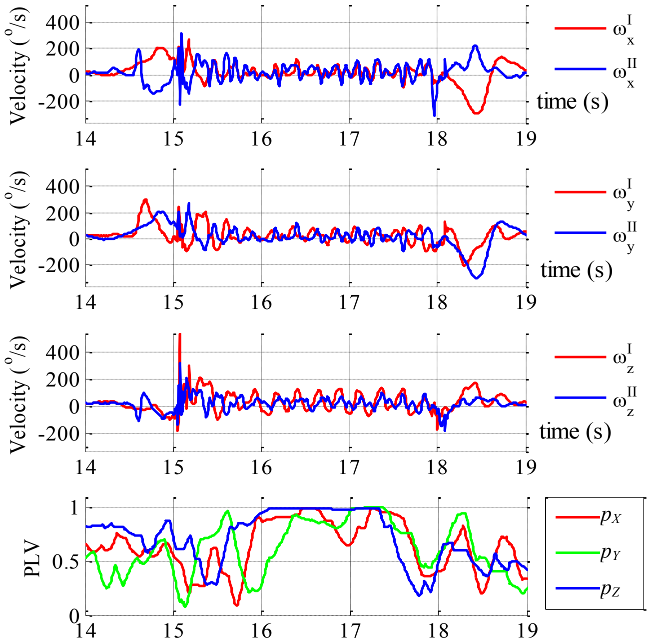

Figure 4. Angular velocities measured in the coordinate frame of the IMU during a handshake and PLV. Axis *z* for velocity corresponds to axis y for accelerations (see Fig. 1).

The PLV applied to these signals shows that synchronization seems to start 0.5 s later than when it is computed based on acceleration values. As the linear acceleration expresses better the vigor and the dynamics of the handshake, the PLV will be computed on accelerations ay in the rest of the paper. The PhC phase is defined in the interval of time from the first contact measured with the force sensors till the PLV becomes equal to 1 (Fig. 3). The MS phase is defined in the time interval where PLV is maintained at 1.0.

The fig. 5 shows a frequency analysis during the handshake. A fast Fourier transformation (FFT) is applied to the acceleration signals during PhC and MS phases. For the two subjects, in the PhC phase, the main values of the frequencies are approximately distributed in the two large lobes [1Hz - 6 Hz] and [6Hz - 10 Hz]. For the MS phase the main frequency appears around 4Hz with a narrow bandwidth of 1.5Hz. This difference means that, during the handshake, there is a shift of the frequency of the movement from an unsynchronized rhythmic movement to a stable synchronized rhythmic movement. This phenomenon is statically analyzed in the next subsection.

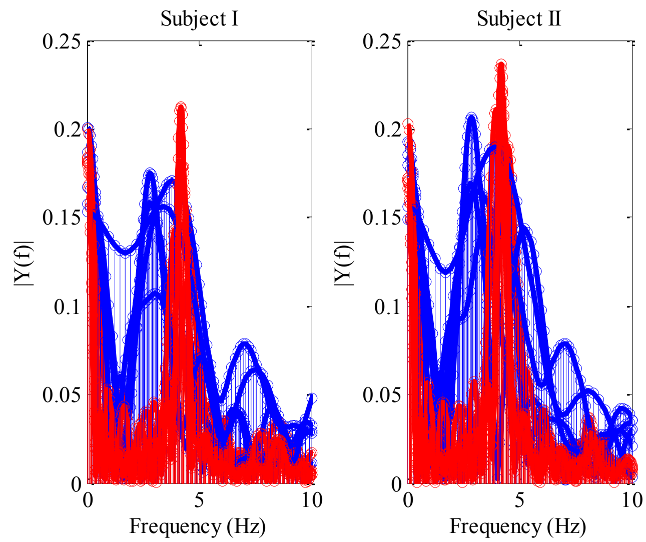

Figure 5. Superposed views of 5 handshakes of one pair of subjects (PhC Phase in blue, MS phase in red). The frequency equal to zero corresponds to the constant values in the signals at the beginning and end of hanshakes.

C. Statistical analysis of a handshake

Aiming to prepare for future experiments with a large number of persons, preliminary experiments to analyze frequencies and durations of the handshake were carried out for six couples of persons (men from 20 to 45 years old) four handshakes per couple, i.e. 24 mixed handshakes. The goal of these experiments was unknown for the participants.

A statistical analysis of frequency shows the average of spectrums for the two phases in Fig. 6. For the PhC phase, frequencies are distributed around 3.2 Hz but with a wide band of 3 Hz. In the MS phase, the main frequency of 4.2 Hz with a narrow band of 1 Hz appears again. Amplitudes are approximately the same in the two phases. Thus, during the handshake, the movement synchronizes and accelerates to reach the frequency around 4 Hz and the two human upper limbs are coupled in a stable cycle limit. This seems to mean that people "are not yet familiar physically" before MS. When the synchronization appears at the common frequency, people seem to communicate physically.

The frequency around 4Hz suggests that the subjects shake their hand rather fast. This surprising result must be confirmed by other future additional experiments. Indeed, the frequency of handshaking may depend on the psychological state of one of the persons. But in all cases, a humanoid robot must be able to reproduce the motion of this frequency in secure conditions if it handshakes with a human.

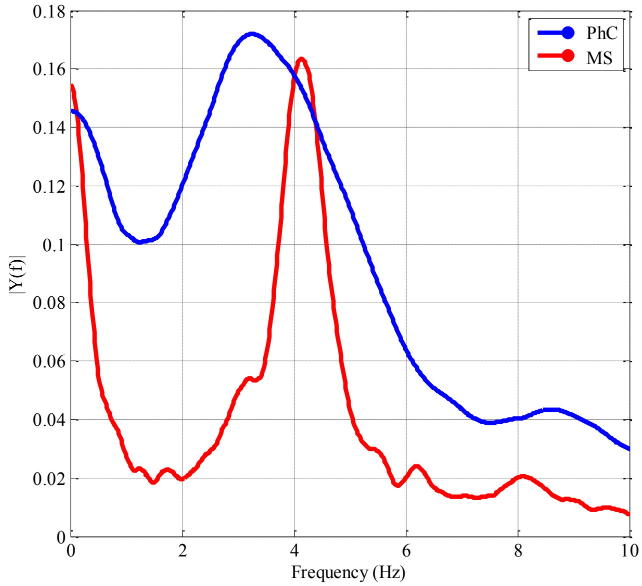

Figure 6. Average of spectrums (FFT) for PhC-phase (blue) and MS-phase (red) obtained for 24 handshakes.

The fig. 7 shows the average duration of the two phases for all the couples of persons. The MS phase is almost three times wider than the PhC phase. The PhC phase is almost the same for all the handshakes. Notice that the average strength force measured during the handshake is around 2.5N.

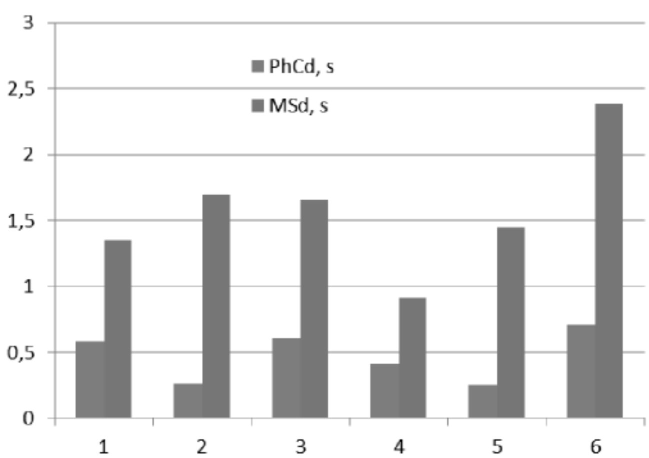

Figure 7. Duration analysis of PhC-phase (left) and MS-phase (right) for the six human couples.

IV. Conclusion

The synchrony is a natural behavioral property of people. In this paper, we have shown that a handshake has four main phases. During the rhythmic physical interaction, in the first phase, the movements occur asynchronously, in the other phase they are phase-locked. Experiments have shown that a phenomenon of physical synchronization occurs during the handshake. Statistical analysis shows that the fundamental frequency of the movement in the synchronization phase is around 4 Hz and the average strength force is about 2.5 N for all the subjects. This frequency of 4 Hz is a surprising result.

In future works, we will investigate a large number of handshaking experiments with a large pool of human subjects including several coded social behavior for subjects. The results will provide behavior models that we could implement in a compliant robotic arm in order to reproduce handshaking between a human and robots. Moreover, it will be necessary to model and simulate personalities, and to investigate how perception (eye contact, temperature and humidity of the hand) can influence on the handshaking.

Acknowledgment

Thanks to Dr. Viacheslav Khomenko for his help in inertial sensors calibration and data acquisition. Thanks also to Olga Kuksina for linguistic editing of the article.

This work is partially supported by the French Embassy in Ukraine and by the INTERACT French project referenced ANR-09-CORD-014.

References

[1] R. Alami, A. Albu-Schaeffer, A. Bicchi, R. Bischoff, R. Chatila, A. D. Luca, A. D. Santis, G. Giralt, J. Guiochet, G. Hirzinger, F. Ingrand, V. Lippiello, R. Mattone, D. Powell, S. Sen, B. Siciliano, G. Tonietti, and L. Villani, "Safe and dependable physical Human-Robot interaction in anthropic domains: State of the art and challenges," in Proc. IROS Workshop on pHRI - Physical Human-Robot Interaction in Anthropic Domains, A. Bicchi and A. D. Luca, Eds., Beijing, China, Oct. 2006.

[2] A. De Santis, B. Siciliano, A. De Luca, and A. Bicchi, "An atlas of physical human–robot interaction," Mechanism and Machine Theory, vol. 43, no. 3, pp. 253-270, Mar. 2008.

[3] P. H. Kahn, H. Ishiguro, B. Friedman, and T. Kanda, "What is a human? - toward psychological benchmarks in the field of Human-Robot interaction," in Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE Int. Symp. on., pp. 364-371.

[4] E. Gribovskaya, A. Kheddar, and A. Billard, "Motion learning and adaptive impedance for robot control during physical interaction with humans," in Robotics and Automation (ICRA), 2011 IEEE International Conference on. IEEE, May 2011, pp. 4326-4332.

[5] M. Huber, M. Rickert, A. Knoll, T. Brandt, and S. Glasauer, "Human-robot interaction in handing-over tasks," in Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on. IEEE, Aug. 2008, pp. 107-112.

[6] A. de Rengerve, J. Hirel, P. Andry, M. Quoy, and P. Gaussier, "On-line learning and planning in a pick-and-place task demonstrated through body manipulation," in Development and Learning (ICDL), 2011 IEEE Int. Conf. on, vol. 2. IEEE, Aug. 2011, pp. 1-6.

[7] K. Dautenhahn, S. Woods, C. Kaouri, M. L. Walters, K. L. Koay, and I. Werry, "What is a robot companion - friend, assistant or butler?" in Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ Int. Conf. on. IEEE, Aug. 2005, pp. 1192-1197

[8] B. Lacevic and P. Rocco, "Kinetostatic danger field - a novel safety assessment for human-robot interaction," in Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ Int. Conf. on. IEEE, pp. 2169-2174.

[9] S. Haddadin, A. Albu-Schaffer, and G. Hirzinger, "The role of the robot mass and velocity in physical human-robot interaction - part i: Non-constrained blunt impacts," in Robotics and Automation. ICRA 2008. IEEE Int. Conf.on. IEEE, May 2008, pp. 1331-1338

[10] M. Jindai and T. Watanabe, "Development of a handshake request motion model based on analysis of handshake motion between humans," in Advanced Intelligent Mechatronics (AIM), 2011 IEEE/ASME Int. Conf. on. IEEE, Jul. 2011, pp. 560-565.

[11] T. Kasuga and M. Hashimoto, "Human-Robot handshaking using neural oscillators," in Robotics and Automation. ICRA 2005. Proceedings of the 2005 IEEE Int. Conf. on. IEEE, pp. 3802-3807.

[12] G. Xie, M. Jin, D. Wu, and M. Hashimoto, "Control for physical human-robot interaction based on online update of dynamics," in Computer Science and Automation Engineering (CSAE), 2011 IEEE Int. Conf. on, vol. 2. IEEE, Jun. 2011, pp. 280-284.

[13] N. Vanello, D. Bonino, E. Ricciardi, M. Tesconi, E.P. Scilingo, V. Hartwig, A. Tognetti, G. Zupone, F. Cutolo, G. Giovannetti, P. Pietrini, D. De Rossi, and L. Landini, "Neural correlates of human-robot handshaking," Proceedings - IEEE International Workshop on Robot and Human Interactive Communication, pp. 555-561, 2010.

[14] N. Kawarazaki, Y. Kitajima, K. Kojima and T.Yoshidime, "Communication robot system based on the handshaking action," 2010 World Automation Congress, WAC 2010, art. no. 5665700

[15] Y. Zeng, Y. Li, P. Xu, S.S. Ge, "Human-robot handshaking: A hybrid deliberate/reactive model," (2012) Lecture Notes in Computer Science, 7621 LNAI, pp. 258-267

[16] D. Schiffrin, “Handwork as Ceremony: The Case of the Handshake,” Semiotica. 12(3): 185-280. doi:10.1515/semi.1974.12.3.189

[17] F. J. Bernieri and K. N. Petty, “The influence of handshakes on first impression accuracy,” Social Influence, vol. 6, no. 2, pp. 78–87, 2011.

[18] P. M. Hall and D. A. S. Hall, “The handshake as interaction,” Semiotica. 45(3-4): 191-379. doi:10.1515/semi.1983.45.3-4.249

[19] J. Golubchik, N. Sever, G. Katz, Shoval, and A. Weizman, “Handshaking as a measure of social responsiveness in patients with autistic spectrum disorder.” Comprehensive psychiatry, vol. 53, no. 6, pp. 805–808, Aug. 2012.

[20] J. Aström and L. H. Thorell, “Greeting behaviour and psychogenic need: interviews on experiences of therapists, clergymen, and car salesmen.” Perceptual and motor skills, vol. 83, no. 3 Pt 1, pp. 939–956, Dec. 1996. http://view.ncbi.nlm.nih.gov/pubmed/8961332

[21] J. Astrom, “Introductory greeting behaviour: a laboratory investigation of approaching and closing salutation phases, Perceptual and Motor Skills, Vol 79(2), Oct 1994, 863-897. doi: 10.2466/pms.1994.79.2.863

[22] W. F. Chaplin, J. B. Phillips, J. D. Brown, N. R. Clanton, and J. L. Stein, “Handshaking, gender, personality, and first impressions.” Journal of personality and social psychology, vol. 79, no. 1, pp. 110–117, Jul. 2000.

[23] A. Pikovsky, M. Rosenblum and J. Kurth. Synchronization: a universal concept in nonlinear sciences, Cambridge, 2001.

[24] R. Schmidt and M. Richardson, "Dynamics of interpersonal coordination," in Coordination: Neural, Behavioral and Social Dynamics, ser. Understanding Complex Systems, A. Fuchs and V. Jirsa, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, vol. 17, ch. 14, pp. 281-308.

[25] S. Hasnain, G. Mostafaoui, and P. Gaussier, "A synchrony-based perspective for partner selection and attentional mechanism in human-robot interaction," vol. 3, no. 3, pp. 156-171, 2012.

[26] Q. Shen, H. Kose-Bagci, J. Saunders, and K. Dautenhahn, "The impact of participants' beliefs on motor interference and motor coordination in Human-Humanoid interactions," Autonomous Mental Development, IEEE Transactions on, vol. 3, no. 1, pp. 6-16, 2011.

[27] R. Ronsse, N. Vitiello, T. Lenzi, J. van den Kieboom, M. C. Carrozza, and A. J. Ijspeert, "Human-Robot synchrony: Flexible assistance using adaptive oscillators," Biomedical Engineering, IEEE Transactions on, vol. 58, no. 4, pp. 1001-1012, Apr. 2011.

[28] A.A. Melnyk, M. V. Khomenko, V. Ph. Borysenko, and P. Hénaff, Physical Human-Robot Interaction in the handshaking case: Learning of rhythmicity using oscillators neuron, IFAC Conf. on Manufacturing Modelling, Management, and Control, Russia, pp. 1089 – 1094, 2013.

[29] A. Melnyk, V. Khomenko, V. Ph. Borysenko, and P. Henaff, "Sensor network architecture to measure characteristics of a handshake between humans," in Proc. of IEEE XXXIV Int. Sci. Conference Electronics and Nanotechnology (ELNANO’2013) pp. 264-268.

[30] A. Augimeri, G. Fortino, M. R. Rege, V. Handziski, and A. Wolisz, “A cooperative approach for handshake detection based on body sensor networks,” in Systems Man and Cybernetics (SMC), 2010 IEEE International Conference on. IEEE, Oct. 2010, pp. 281–288.

[31] J. P Lachaux, E. Rodriguez, J. Martinerie and F.J. Varela. Measuring phase synchrony in brain signals. Human Brain Mapping, 1999.